CONSIDERATIONS FOR SPACECRAFT DESIGN FOR M-SAT

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ABSTRACT

The paper describes the system design considerations and design activities performed at Spar Aerospace in the last eighteen months in support of the development of a Canadian Mobile Communication satellite (M-SAT).

Recent evolving international agreements and events of importance to M-SAT are the emergence of the U.S. Operator and the Mobile WARC 1987. Their impacts on the system requirements and system design are discussed.

Solutions to these new requirements are implemented into the 9 Beam baseline design. The system design and the parallel technology development enable Spar Aerospace to be ready to support a commercial flight program.

INTRODUCTION

Canada has been persuing for some years the study of systems and technology for a Canadian Mobile Satellite System (M-SAT). Agreements between the Department of Regional Industrial Expansion and Spar Aerospace has provided funding for the development of the M-SAT space segment, work which is reported in this paper.

Since July 1986, a number of events in the United States and in Canada[a] have quickened the pace of commercial M-SAT development. Recently evolving international agreements and events have added other considerations to the system design. Of particular importance has been the emergence of the U.S. Operator and the desire of the U.S. and Canadian Operators to provided interoperable systems. The Mobile WARC conference in 1987 has established the L-band as the frequency band for mobile satellite service and has added some complexity to the L-band power and frequency flexibility requirements.

This paper will describe the current work at Spar Aerospace on the development of an all L-band system where the above requirements have been considered.

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a Kidd, 1987

SYSTEM REQUIREMENTS

Basic System Design Requirements and Guidelines

The system design based on Canadian requirements of the L-band M-SAT space segment are to provide full Canadian coverage, full CONUS/Alaska backup coverage and to provide sufficient capability to support 60,000 Canadian Users with a ten year lifetime.

The system design resulting from these requirements is to stay within the following guidelines:

1) The spacecraft should be designed such that it can be launched by an Ariane IV vehicle as part of a dual launch. However, the spacecraft should be configured to take advantage of evolving expendible launch vehicle systems.
2) The payload mass should be maintained below 350 kg (770 lbs) without margin and the payload DC power should be maintained below 2500 Watts without margin.
3) The payload should be configured for a typical three axis body stabilized spacecraft.
4) The overall system should be designed for a mix of service: 40% transportable and 60% ground mobile, with 12 dBi and 9 dBi respective mobile antenna gain.

This is to constrain the final design of the payload while maintaining the desired performance. Spacecraft with the above weight and power capabilities are now being built for the latest generation of domestic communication satellites.

Impacts of Mobile WARC 1987

Prior to Mobile WARC 1987, the system design and the technology development have been based on a 9 MHz continuous spectrum in accordance with the Federal Communication Commission (FCC)[b] frequency allocation. However, a two segment L-band allocation for LMSS spanning 29 MHz has been established by Mobile WARC 1987.

There is some indication that the M-SAT operators might want to provide service in four bands, namely, MMSS, AMSS and the two segments of spectrum allocated to LMSS by Mobile WARC 1987[c], for the first generation system.

This new requirement along with the need for flexibility for evolving user demands and distribution lead to the following update of the pre WARC design:

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b Brassard, 1988

c WARC MOB-87

Impacts of Mobile WARC 1987 (cont'd)

1) Minimization of back-haul spectrum and optimization of L-band spectrum efficiency/flexibility.
2) Interaction (trade-offs) between back-haul power and L-band spectrum efficiency/flexibility.
3) Local Oscillator frequency generation and IF plan to take into account the much larger number of sub-bands required.
4) Intermodulation analysis taking into account the discontinuous nature of signal spectrum in the new frequency plan.
5) A wider instantaneous bandwidth (i.e. 29 vs 9 MHz) is required for the L-band high power amplifier.
6) Passive Inter Modulation (PIM) performance of L-band antenna components taking into account the reduction of PIM order from 15th to 7th.
7) L-band input/output filter performance taking into account the wider operating bandwidth and the narrower separation between transmit and receive bands.

Impacts of the Interoperable North American System

The emergence of the U.S. Operator has brought up the following additional considerations to the M-SAT space segment design:

1) The system design should involve both a Canadian and U.S. spacecraft with a primary mode of servicing their respective territories. Prior to launch of the second spacecraft, or in the case of one of the spacecraft failing, either spacecraft should be capable of providing both a Canadian and a U.S. service up to the capacity of a single spacecraft.
2) The concept should allow the two spacecraft to occupy orbital slots separated by up to 20 degrees of longitude.
3) The spacecraft hardware for both the Canadian and the U.S. spacecraft should be functionally identical.

The first and third considerations have no technical impact on the system design. The mass, power, coverage and frequency reuse provided in the basic design requirements are sufficient to cover these new items.

The second consideration requires some adjustment to the 9 Beam L-band antenna coverage pattern.

SYSTEM DESIGN

Concept Trade-off

Two candidate system concepts for the M-SAT space segment have been considered: the conventional spot beam approach (with varying amounts of overlap) and the scanning system employing the Frequency Addressable Beam (FAB) technique. Prior to Mobile WARC 1987, a complete trade-off study had been made between the 9 Beam concept and the FAB concept. The following parameters have been studied:

1) DC Power
2) Spacecraft mass
3) System capacity
4) System reliability
5) System flexibility including
   - Operation with two co-located satellites
   - System growth potential
6) Technical risk including
   - PIM
   - Deployments

The study result has shown that neither of the two schemes offers overriding advantages. However, after Mobile WARC 1987 and the decision to provide full 29 MHz service, the 9 Beam concept appears to be a better candidate due to its PIM performance (separate versus common transmit/receive antenna in view of the lower order PIM). All efforts have been shifted to cover various design aspects of the 9 Beam concept.

CONCLUSION

A 9 Beam system meeting all the basic design requirements and guidelines, had been defined prior to Mobile WARC 1987[d]. Solutions to the considerations discussed earlier, are being implemented to the baseline design to make it compliant to the requirements as currently understood. Spar Aerospace is considering applying for a patent on the design concept to provide power flexibility.

A parallel technology development of payload units, in support of the system concept, is well advanced at Spar Aerospace[e].

Possible modifications of the requirements such as the addition of Mexican coverage can easily be implemented in the updated baseline design.

The system design activities and the parallel technology development enable Spar Aerospace to be ready to support a commercial flight program.

REFERENCES

Kidd, A.M., Karlsson, I., Whittaker, N., 1987. M-SAT System and Payload Development. The Canadian Satellite User Conference, pp. 394-399.

Brassard, G., 1988. L-Band linear high power amplifier using Class C transistors. R.F. Expo '88.

Final Acts of WARC MOB-87

Cox, R.P., Zacharatos, J., Williamson, B., Morgan, C., Cox, J.R.G., 1988. System Trade Off for a North American Mobile Satellite. AIAA 12th ICSSC.

Karlsson, I., Patenaude, Y., Stipelman, L., 1988. Antenna System for M-SAT Mission. JPL Mobile Satellite Conference.

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d Cox, 1988

e Karlsson, 1988